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Title: Sensitivity Analysis and Uncertainty Quantification of the Feynman Y and Sm2

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Project Title

Sensitivity Analysis and Uncertainty Quantification of the Feynman Y and Sm_2

Project Objective

To compute the uncertainty in the Feynman Y and Sm_2 due to uncertainty in nuclear cross sections using Sean O'Brien's sensitivity analysis (SA) methodology [1].

Project Description

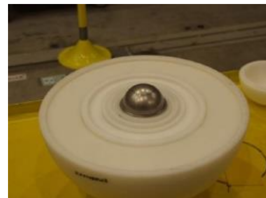
Neutron multiplicity counting (NMC) experiments are frequently used to perform non-destructive assay (NDA) of special nuclear material (SNM) [2]. While the behavior of a critical or nearly critical system is well described by the mean count rate, which is the mean of the NMC distribution, the behavior of a highly subcritical system exhibits large fluctuation in time. Fission chains do not last long enough to overlap and thus the neutron population is relatively small with a large dispersion. The system behavior must therefore be described in terms of higher-order NMC distribution moments.

Y and Sm_2 are both ratios of moments of the NMC distribution. The Feynman Y variance-to-mean ratio has historically been used to infer integral properties of SNM, such as neutron lifetime and neutron multiplication, but requires knowledge of the detector response function [3, 4]. The Sm_2 doubles-to-singles-squared ratio is a relatively new method of NDA of SNM and is independent of the detector response function, making it useful in comparing characterizations of the same SNM counted by different detectors [5, 6].

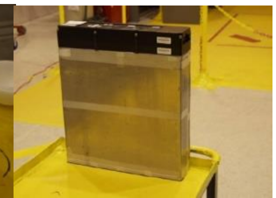
Project Relevance to Nuclear Nonproliferation

Simulations of Y and Sm_2 require nuclear cross sections and fission parameters as inputs. Because these transport parameters are themselves uncertain, reliable characterization of SNM requires sensitivity analysis and uncertainty quantification (SA/UQ) of Y and Sm_2.

Products and Outcomes of Project



BeRP ball nested in polyethylene reflectors



nPod neutron multiplicity counter

We have used PARTISN simulations of NMC experiments of the nPod neutron multiplicity counter counting a 4.5 kg sphere of weapons-grade plutonium metal, a.k.a. the BeRP ball, to perform SA/UQ of Y and Sm_2. We observed that Sm_2 has less uncertainty than Y due to uncertainty in the transport parameters [7, 8]. While Y has been used extensively for NDA of SNM, no such analysis has been performed using Sm_2. It is therefore of interest to develop models of Sm_2 as a function of either reflector thickness or neutron multiplication such that integral quantities of SNM may be estimated with an observable that is independent of the detector response function.

Publications and Reports

A. CLARK, J. A. FAVORITE, A. MCSPADEN, and M. NELSON, "Sensitivity Analysis and Uncertainty Quantification of the Feynman Y and Sm_2," *Trans. Of the Am. Nucl. Soc.*, **119**, article in press (2018)

A. CLARK and J. A. FAVORITE, "Trends in the Feynman Y and Sm_2 vs polyethylene reflector thickness and neutron multiplication," Los Alamos National Laboratory, memo in progress (2018)

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1. S. E. O'BRIEN, J. MATTINGLY, and D. ANISTRATOV, "Sensitivity Analysis of Neutron Multiplicity Counting Statistics for a Subcritical Plutonium Metal Benchmark using First-Order Perturbation Theory," *Nuc. Sci. and Eng.*, **185**, *3*, 406, (2017), https://doi.org/10.1080/00295639.2016.1272988
2. M. SMITH-NELSON, et al., "Neutron Specialist Handbook and Informational Text," Los Alamos National Laboratory, LA-UR-07-6170, (September 2007).
3. J. MATTINGLY, "Computation of Neutron Multiplicity Statistics using Deterministic Transport," IEEE T. Nucl. Sci., **59**, *2*, 314, (2012), https://doi.org/10.1109/NSSMIC.2009.5402335.
4. A. M. OKOWITA and J. MATTINGLY, "Analysis of the Feynman Variance to Mean Ratio using Nonlinear Regression," INMM 53rd Annual Meeting, Orlando, (2012).
5. M. A. SMITH-NELSON and J. D. HUTCHINSON, "The Sm_2 Ratio for Evaluating Neutron Multiplicity Models," Los Alamos National Laboratory, LA-UR-14-29047, (November 2014), https://doi.org/10.2172/1164461.
6. A. MCSPADEN, et al., "Eliminating Detector Response in Neutron Multiplicity Measurements for Model Evaluation," Trans. Am. Nucl. Soc., **117**, Washington, D.C., Oct. 29-November 2, (2017).
7. R. E. ALCOUFFE, et al, "PARTISN: Time-Dependent, Parallel Neutral Particle Transport Code System," Los Alamos National Laboratory, (November 2008).
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